UNIVERSITY OF JOHANNESBURG

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED PHYSICS & ENGINEERING MATHEMATICS

BACHELOR OF ENGINEERING TECHNOLOGY IN CHEMICAL ENGINEERING

MODULE PHYSCA1
ENGINEERING PHYSICS CHEM IA

CAMPUS **DFC**

JULY SUPPLEMENTARY EXAMINATION

DATE: 19 July 2018 **SESSION: 08:00 – 11:00**

ASSESSOR **MR. T.G. Mathe**

INTERNAL MODERATOR **DR. J. Changundega**

DURATION: 3 HOURS **MARKS: 140**

NUMBER OF PAGES: 11 PAGES, INCLUDING 1 DATA SHEET.

INSTRUCTIONS:

- ANSWER ALL THE QUESTIONS.
- KEEP ALL SUB-QUESTIONS TOGETHER. YOU MAY START WITH ANY QUESTION.
- CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).
- START EACH QUESTION ON A NEW PAGE.
- NUMERICAL ANSWERS ARE TO BE EXPRESSED IN SCIENTIFIC NOTATION & CORRECT NUMBER OF SIGNIFICANT FIGURES OBSERVED. SHOW ALL STEPS FOLLOWED IN GETTING TO FINAL ANSWERS.
- WORK WRITTEN IN PENCIL WILL NOT BE MARKED. ONLY DRAWINGS ARE TO BE DONE IN PENCIL.
- NEGATIVE MARKING WILL BE IMPOSED ON ANSWERS DEEMED TO BE IN GROSS VIOLATION OF BASIC SCIENTIFIC PRINCIPLES & LAWS.

REQUIREMENTS: ONE EXAMINATION ANSWER SCRIPT PER STUDENT
ONE UJ MULTIPLE CHOICE CARD

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SECTION A: MULTIPLE CHOICE QUESTIONS [40 marks]

1. Complete the following statement: The ratio $\frac{1\,\text{milligram}}{1\,\text{kilogram}}$ is equal to

   A. 10^2.
   B. 10^3.
   C. 10^6.
   D. 10^{-3}.
   E. 10^{-6}.

2. Which one of the following statements is true concerning scalar quantities?

   A. Scalar quantities must be represented by base units.
   B. Scalar quantities have both magnitude and direction.
   C. Scalar quantities can be added to vector quantities using rules of trigonometry.
   D. Scalar quantities can be added to other scalar quantities using rules of trigonometry.
   E. Scalar quantities can be added to other scalar quantities using rules of ordinary addition.

3. A net force **F** is required to give an object with mass *m* an acceleration **a**. If a net force 6 **F** is applied to an object with mass 2*m*, what is the acceleration on this object?

   A. **a**
   B. 2**a**
   C. 3**a**
   D. 4**a**
   E. 6**a**

4. Consider the following forces

   (*1*) frictional
   (*2*) gravitational
   (*3*) tension
   (*4*) nuclear
   (*5*) normal
   (*6*) weak interactions

   Which of the forces listed are considered fundamental forces?

   A. *1*, *2*, and *4*
   B. *1*, *2*, *3*, and *5*
   C. *1*, *3*, and *5*
   D. *2*, *4*, and *6*
   E. *2*, *3*, *4*, and *6*

5. A ball is whirled on the end of a string in a horizontal circle of radius *R* at constant speed *v*. Complete the following statement: The centripetal acceleration of the ball can be increased by a factor of 4 by

   A. keeping the speed fixed and increasing the radius by a factor of 4.
   B. keeping the radius fixed and increasing the speed by a factor of 4.
   C. keeping the radius fixed and increasing the period by a factor of 4.
   D. keeping the radius fixed and decreasing the period by a factor of 4.
   E. keeping the speed fixed and decreasing the radius by a factor of 4.

6. An elevator supported by a single cable, descends a shaft at a constant speed. The only forces acting on the elevator are the tension in the cable and the gravitational force. Which one of the following statements is **true**?

A. The magnitude of the work done by the tension force is larger than that done by the gravitational force.
B. The magnitude of the work done by the gravitational force is larger than that done by the tension force.
C. The work done by the tension force is zero joules.
D. The work done by the gravitational force is zero joules.
E. The net work done by the two forces is zero joules.

7. A rock is dropped from a high tower and falls freely under the influence of gravity. Which one of the following statements concerning the rock as it falls is true? Neglect the effects of air resistance.

A. The rock will gain an equal amount of momentum during each second.
B. The rock will gain an equal amount of kinetic energy during each second.
C. The rock will gain an equal amount of speed for each metre through which it falls.
D. The rock will gain an equal amount of momentum for each metre through which it falls.
E. The amount of momentum the rock gains will be proportional to the amount of potential energy that it loses.

8. A simple pendulum consists of a ball of mass m suspended from the ceiling using a string of length L. The ball is displaced from its equilibrium position by a small angle θ. What is the magnitude of the restoring force that moves the ball toward its equilibrium position and produces simple harmonic motion?

A. kx
B. mg
C. $mg\cos\theta$
D. $mg\sin\theta$
E. $mgL\sin\theta$

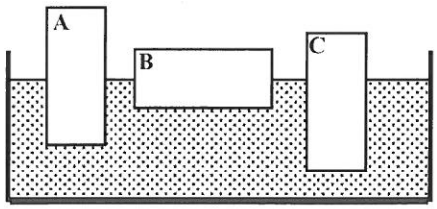
9. Which one of the following statements is true concerning an object executing simple harmonic motion?

A. The object's velocity is never zero.
B. The object's acceleration is never zero.
C. The object's velocity and acceleration are simultaneously zero.
D. The object's velocity is zero when its acceleration is a maximum.
E. The object's maximum acceleration is equal to its maximum velocity.

10. A mass of sunken lead is resting against the bottom in a glass of water. You take this lead, put it in a small boat of negligible mass, and float the boat in water. Which of the following statements is TRUE?

A. The sunken lead displaces a volume of water equal to the lead's own volume.
B. The floating lead displaces a volume of water equal to the lead's own volume.
C. The sunken lead displaces a volume of water whose weight equals the lead's weight.

11. Three blocks, labeled A, B, and C, are floating in water as shown in the drawing. Blocks A and B have the same mass and volume. Block C has the same volume, but is submerged to a greater depth than the other two blocks. Which one of the following statements concerning this situation is false?



A. The density of block A is less than that of block C.
B. The buoyant force acting on block A is equal to that acting on block B.
C. The volume of water displaced by block C is greater than that displaced by block B.
D. The buoyant force acting on block C is greater than that acting on block B.
E. The volume of water displaced by block A is greater than that displaced by block B.

12. Which one of the following statements concerning a completely enclosed fluid is **true**?

A. Any change in the applied pressure of the fluid produces a change in pressure that depends on direction.
B. The pressure at all points within the fluid is independent of any pressure applied to it.
C. Any change in applied pressure produces an equal change in pressure at all points within the fluid.
D. An increase in pressure in one part of the fluid results in an equal decrease in pressure in another part.
E. The pressure in the fluid is the same at all points within the fluid.

13. Heat is added to a substance, but its temperature does not rise. Which one of the following statements provides the best explanation for this observation?

A. The substance must be a gas.
B. The substance must be a non-perfect solid.
C. The substance undergoes a change of phase.
D. The substance has unusual thermal properties.
E. The substance must be cooler than its environment.

14. Which one of the following statements explains why it is difficult to measure the coefficient of volume expansion for a liquid?

A. Liquids are more compact than solids.
B. Liquids are more compact than gases.
C. Liquids tend to expand more slowly than solids.
D. The liquid will lose heat to the containing vessel.
E. The volume of the containing vessel will also increase.

15. Two cubes, one silver and one iron, have the same mass and temperature. A quantity Q of heat is removed from each cube. Which one of the following properties causes the final temperatures of the cubes to be different?

A. density
B. specific heat capacity
C. volume
D. latent heat of vaporization
E. coefficient of volume expansion

16. Which one of the following statements is *not* a characteristic of a plane mirror?

A. The image is real.
B. The magnification is +1.
C. The image is always upright.
D. The image is reversed right to left.
E. The image and object distances are equal in magnitude.

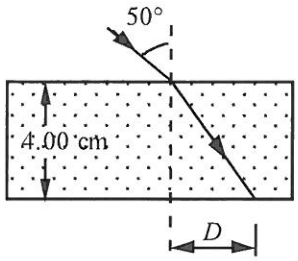
17. Which one of the following statements concerning a convex mirror is true?

A. A convex mirror can form a real image.
B. A convex mirror must be spherical in shape.
C. The image produced by a convex mirror will always be inverted relative to the object.
D. A convex mirror produces a larger image than a plane mirror does for the same object distance.
E. The image a convex mirror produces is closer to the mirror than it would be in a plane mirror for the same object distance.

18. A beam of light passes from air into water. Which is necessarily true?

A. The frequency is unchanged and the *wavelength increases.*
B. The frequency is unchanged and the *wavelength decreases*.
C. The wavelength is unchanged and the *frequency decreases.*
D. Both the wavelength and frequency *increase*.
E. Both the wavelength and frequency *decrease*.

19. A ray of light passes from air into a block of glass with a refractive index of 1.50 as shown in the figure.
Note: *The drawing is not to scale.*
What is the value of the distance *D*?



A. 1.42 cm
B. 1.66 cm
C. 1.90 cm
D. 2.14 cm
E. 2.38 cm

20. Which one of the following expressions determines the critical angle for quartz (n = 1.5) immersed in oil (n = 1.1)?

A. $\theta_C = 1.5/1.1$
B. $\theta_C = \sin^{-1}(1.1/1.5)$
C. $\theta_C = \tan^{-1}(1.1/1.5)$
D. $\theta_C = 1.1/1.5$
E. $\theta_C = \sin(1.1/1.5)$

SECTION B: LONG QUESTIONS [100 marks]

QUESTION 1: MECHANICS [30 marks]

1.1 Consider the following vectors

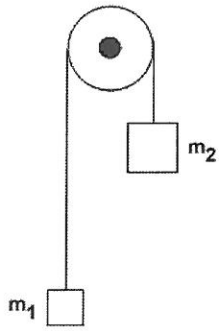
$\overrightarrow{A} = (6.00\,\hat{\imath} - 8.00\,\hat{\jmath})$ units,

$\overrightarrow{B} = (-8.00\,\hat{\imath} + 3.00\,\hat{\jmath})$ units, and

$\overrightarrow{C} = (26.0\,\hat{\imath} + 19.0\,\hat{\jmath})$ units

Determine the constants *a* and *b* such that $a\overrightarrow{A} + b\overrightarrow{B} + \overrightarrow{C} = 0$ **(4)**

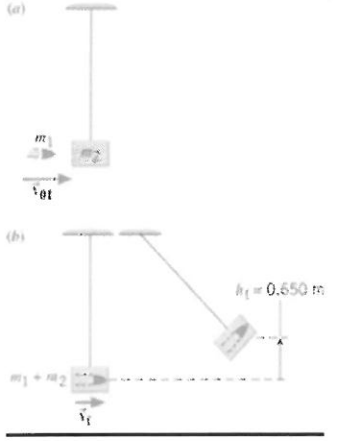
1.2 In an *Atwood Machine*, two masses m_1 and m_2 (assume $m_2 > m_1$), are connected by a massless string that passes over a frictionless pulley, as shown below. Determine the acceleration of the masses **and** the tension in the string. **(6)**



1.3 A 3.00 kg block starts from rest at the top of a 30.0° incline and slides a distance of 2.00 m down the incline in 1.50 s. Calculate

1.3.1 the magnitude of the acceleration of the block, **(2)**
1.3.2 the friction force acting on the block, **(3)**
1.3.3 the coefficient of kinetic friction between block and plane, **(4)**
1.3.4 the speed of the block after it has slid 2.00 m. **(2)**

1.4 The diagram below shows a simplest form of a ballistic pendulum; a system for measuring the speed of a bullet. The bullet with mass m_1 = 5.00 g is fired into a block of wood with mass m_2 = 2.00 kg suspended like a pendulum. The bullet makes a completely inelastic collision with the block, becoming embedded in it. After the impact of the bullet, the block swings up to a maximum height h_f = 0.650 m. Calculate the initial speed of the bullet, v_{01}. **(9)**

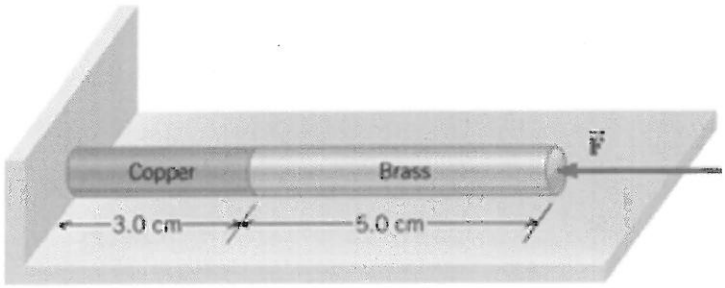


QUESTION 2: ELASTICITY [20 marks] Start on a new page

2.1 A copper cylinder and a brass cylinder are stacked end to end, as in the drawing. Each cylinder has a radius of 0.25 cm. A compressive force of F = 6500 N is applied to the right end of the brass cylinder. Find the amount by which the length of the stack decreases. **(10)**

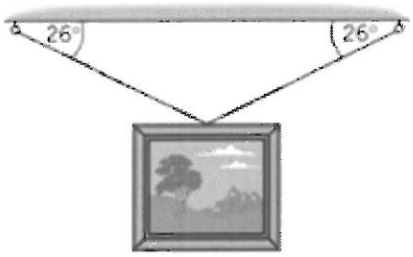
Young's Modulus of copper = 1.1 × 10^{11} N·m^{-2}

Young's Modulus of brass = 9.0× 10^{10} N·m^{-2}



2.2 A steel wire is strung between two supports attached to a ceiling. Initially, there is no tension in the wire when it is horizontal. A 96 N picture is then hung from the left of the wire, as the drawing illustrates, so the ends of the wire make angles of 26° with respect to the horizontal. What is the radius of the wire? **(10)**

[Young's Modulus of steel = 2.0 × 10^{11} N·m^{-2}]



QUESTION 3: HYDROSTATICS [20 marks] Start on a new page

3.1 The main water line enters a house on the first floor. The line has a gauge pressure of 1.90×10^5 Pa.

3.1.1 A tap on the second floor, 6.50 m above the first floor, is turned off. What is the gauge pressure at this tap? **(4)**

3.1.2 How high could a tap be before no water would flow from it, even if the tap were open? **(3)**

Density of water = 1.00×10^3 kg·m^{-3}
Acceleration due to gravity = 9.80 m·s^{-2}

3.2 In the process of changing a flat tyre, a motorist uses a hydraulic jack. She begins by applying a force of 45 N to the input piston, which has a radius r_1. As a result, the output piston, which has a radius r_2, applies a force to the car. The ratio r_2/r_1 has a value of 8.3. Ignore the height difference between the input piston and output piston and determine the force that the output piston applies to the car. **(5)**

3.3

3.3.1 Calculate the buoyant force of air on a spherical party balloon that has a radius of 15.0 cm. **(4)**

3.3.2 If the rubber of the balloon itself has a mass of 2.00 g and the balloon is filled with helium, calculate the net upward force (the "lift") that acts on it in air. **(4)**

Density of air = 1.20 kg·m^{-3}
Density of helium = 0.166 kg·m^{-3}

QUESTION 4: THERMAL PHYSICS [18 marks] Start on a new page

4.1 A simple pendulum consists of a ball connected to one end of a thin brass wire. The period of the pendulum is 2.0000 s. The temperature rises by 140 C°, and the length of the wire increases. Determine the period of the heated pendulum. **(6)**

Coefficient of linear expansion of brass = 19×10^{-6} (°C)$^{-1}$

4.2 When 4200 J of heat are added to a 0.15 m long silver bar, its length increases by 4.3×10^{-3} m. What is the mass of the bar? **(6)**

Specific heat capacity of silver = 235 J·kg^{-1}·°C^{-1}
Coefficient of linear expansion for silver = 19×10^{-6} °C^{-1}

4.3 A thin spherical shell of silver has an inner radius of 2.0×10^{-2} m when the temperature is 18 °C. The shell is heated to 147 °C. Find the change in the interior volume of the shell. **(6)**

Coefficient of volume expansion for silver = 57×10^{-6} °C^{-1}

QUESTION 5: GEOMETRICAL OPTICS [12 marks] Start on a new page

5.1 The image produced by a concave mirror is located 26 cm in front of the mirror. The focal length of the mirror is 12 cm. How far in front of the mirror is the object located? **(4)**

5.2 State Snell's law of refraction. **(2)**

5.3 A beam of light is traveling in air and strikes a material. The angles of incidence and refraction are 63.0° and 47.0°, respectively. Obtain the speed of light in the material. **(6)**

Refractive index of air = 1.000

Speed of light in air = 3.00×10^8 m·s^{-1}

END

USEFUL INFORMATION

MECHANICS & ELASTICITY

$g\ (earth) = 9.80\ m.s^{-2}$

$x = v_o t + \frac{1}{2}at^2$

$v = v_o + at$

$v^2 = v_o^2 + 2ax$

$x = \frac{1}{2}(v_o + v)t$

$f = \mu F_N$

$w = mg$

$\sum \overrightarrow{F} = m\overrightarrow{a}$

$v = \sqrt{\frac{GM_E}{r}}$

$\tan\theta = \frac{v^2}{rg}$

$v = \frac{2\pi r}{T}$

$A\ (circle) = \pi r^2$

$E_k = \frac{1}{2}mv^2$

$E_p = mgh$

$\overrightarrow{p} = m\overrightarrow{v}$

$\bar{P} = \frac{W}{t} = \bar{F}v$

$W = Fxcos\theta$

$W = \Delta E_k$

$T = 2\pi\sqrt{\frac{L}{g}}$

$F = Y\left(\frac{\Delta L}{L_o}\right)A$

$f = \frac{1}{T}$

$F_c = \frac{mv^2}{r}$

$F_g = \frac{Gm_1m_2}{r^2}$

$\bar{F}t = \Delta p$

HYDROSTATICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$F_B = \rho V g$

$P_{abs} = P_{atm} + \rho gh$

$P_{atm} = 1.01 \times 10^5\ Pa$

$P = \rho gh$

THERMAL PHYSICS

$\Delta L = \alpha L_o \Delta T$

$\Delta V = \beta V_o \Delta T$

$Q = mL_f$

$Q = mL_v$

$Q = mc\Delta T$

GEOMETRICAL OPTICS

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$m = \frac{h_i}{h_o} = -\frac{v}{u}$

$f = \pm\frac{R}{2}$

$n_1 sin\theta_1 = n_2 sin\theta_2$

$n = \frac{c}{v}$